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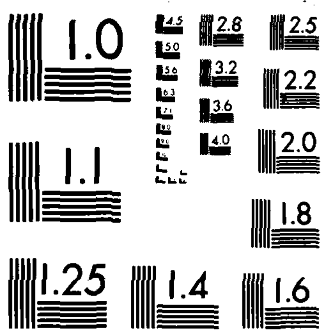

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A RAND NOTE

FORECASTING WARTIME DEPOT-LEVEL COMPONENT WORKLOADS

N. Y. Moore, L. B. Embry, P. K. Dey

January 1985

N-2271-NAVY

Prepared for

The Department of the Navy

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This research was sponsored by the Department of the Navy
under Contract No. N00014-83-C-0100.

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER N-2271-NAVY	2. GOVT ACCESSION NO. AD-A155 168	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Forecasting Wartime Depot-Level Component Workloads		5. TYPE OF REPORT & PERIOD COVERED Interim
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) N. Y. Moore, L. B. Embry, P. K. Dey		8. CONTRACT OR GRANT NUMBER(s) N00014-83-C-0100
9. PERFORMING ORGANIZATION NAME AND ADDRESS The Rand Corporation 1700 Main Street Santa Monica, CA. 90406		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS The Department of the Navy Office, Assistant Secretary of the Navy Washington, DC 20360		12. REPORT DATE January 1985
		13. NUMBER OF PAGES 31
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release; Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

No Restrictions

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Forecasting	Maintenance
Logistics Management	Repair
Logistics Planning	Work Measurement
Spare Parts	Navy

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

See reverse side

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

The Navy needs accurate forecasts of wartime depot-level component repair workloads to size facilities, choose repair sources, and plan future depot modernization efforts. This Note describes and demonstrates a model that can be used to forecast wartime depot-level component repair workloads. The analysis highlights potential tradeoffs among stock, distribution, and repair, and demonstrates that the timing and magnitude of the depot workload are sensitive to distribution and repair times as well as sortie and attrition rates. The study suggests that improved component management systems that shorten the repair and transportation pipelines would enhance the ability of the Navy's depots to support the operational forces in wartime.

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PREFACE

This study was prepared for the Office of the Assistant Secretary of the Navy (Shipbuilding and Logistics) under Contract N00014-83-C-0100, "Improving Wartime Capability and Logistics Support Resources Management for Naval Aviation." The primary tasks were to demonstrate and deliver a model that can be used to forecast wartime depot-level component repair workloads.

This Note describes and demonstrates the model. The study should be of interest to the Naval Aviation Logistics Center, the Aviation Supply Office, and other organizations concerned with estimating workload, determining depot capacity, and establishing the role of the depot in supporting Naval aviation forces during wartime.

SUMMARY

The Navy needs accurate forecasts of wartime depot-level component repair workload to size facilities, choose repair sources, and plan future depot modernization efforts. Because the Navy had difficulty generating accurate forecasts, Rand was asked to (1) demonstrate an improved methodology for estimating wartime depot-level component workloads, and (2) transfer the model developed to the Navy.

Such a methodology was incorporated into an existing Rand model, which was modified further to ease Navy implementation. Outputs include daily demands on depot supply and repair as well as the minimum workload necessary to support future wartime flying.

A prototype evaluation was conducted to demonstrate the usefulness of the model and to test the sensitivity of depot workload to changes in the wartime operational and support scenarios. The analyses highlight potential tradeoffs among stock, distribution, and repair, and demonstrates that the timing and magnitude of the depot workload are sensitive to distribution and repair times as well as sortie and attrition rates. Sensitivity analyses demonstrated that time-phased component arrivals at the depot are a function of distribution system performance, and that workload--defined as the number of components requiring repair--can be dramatically affected by both maintenance performance and stockage position. For example, in one sensitivity analysis, peak component arrivals at the depot were almost 45 percent less than the peak demand on depot supply, and arrive about 50 days later. Such analyses provide insights which are useful in logistics system design as well as capacity requirements definition. They also demonstrate the close interrelationship between scenario assumptions and logistics demands.

Thus, prototype evaluation was designed to illustrate the power of the methodology. While its results may provide one input to the problem of defining depot capacity requirements, more detailed analyses at the shop level are required. The model described in the document can be used by the Navy to support such analyses.

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I. INTRODUCTION

Forecasting wartime depot-level component repair workloads[1] is a difficult and yet necessary task for the Navy. Such forecasts are needed to select sources of repair, to size organic depot facilities, and to guide depot modernization efforts. This Note describes and demonstrates a methodology to assist the Navy in more accurately and efficiently making these forecasts. It also discusses some potential tradeoffs between depot repair, supply, and transportation resources.

BACKGROUND

The need for forecasts of wartime depot-level component repair workload is not new, but until recently it had received relatively little attention in the Navy. In 1981, the Navy initiated the Baseline Study in an attempt to upgrade its depot workload estimates.[2] The study's objective was to identify component repair workload arising from two prescribed wartime operating scenarios and use the workload to estimate the minimum peacetime depot facilities, equipment, manpower, and mix of technical skills needed to ensure that surge capability would be available to meet wartime requirements. The study was performed by the Naval Aviation Logistics Center (NALC) and has subsequently been institutionalized as an annual exercise to provide input to the Navy's Program Objective Memorandum (POM).

Component repair represents a significant portion of peacetime depot workload, and an even larger portion of projected wartime workload.[3] Therefore, sizing the depot and structuring a depot modernization program require good estimates of component repair requirements. Unfortunately, the Baseline Study encountered significant

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[1] Defined here as the number of components arriving daily at the depot.

[2] Part of the impetus for conducting the Baseline Study was the Navy's depot modernization program.

[3] Standard Depot Level Maintenance (SDLM) workload is phased down during wartime.

problems in forecasting wartime component workloads, especially when they tried to use the Aviation Supply Office's (ASO's) Stratification (STRAT) model, and these problems have persisted in subsequent exercises.

The Navy's difficulty in forecasting component workload stems from organizational and analytic disconnects. ASO is responsible for computing component stockage and repair requirements for both peacetime and wartime. However, when ASO computes requirements they assume that the initial wartime surge in demands is satisfied from war reserve stock. (As we will show later, this stockage availability affects wartime repair requirements because wartime workload is dynamic, rather than steady state as in peacetime.) ASO's STRAT model, which is used to estimate the Navy's peacetime procurement and repair requirements, is not suited to the task of computing wartime workload. Consequently, an attempt to use STRAT to forecast repair requirements failed.

The NALC needs estimates of wartime component workloads to develop its depot capacity and facility modernization plans. However, it lacks both the supply data (an ASO responsibility) and the models needed to accurately make such estimates. Indeed, for the Baseline Study the NALC assumed that all failures sent to the depot must be repaired, despite the fact that ASO plans to buy war reserve stock to support the early days of conflict. In the absence of supply data and models, the NALC developed factors by materiel category and used them to escalate peacetime demand experience to wartime activity levels to estimate wartime workload.

The Baseline effort produced a useful first step toward the goal of developing forecasts of wartime depot-level component workload but there are a number of areas where the Navy's analyses could be improved. Current computational methodologies used by supply and maintenance organizations may generate excessive requirements for both stock and repair capability. Furthermore, these methodologies do not support analyses of the interaction of the depot system with other logistics functions, nor can they assess the merits of alternative component repair structures that could support Navy forces more effectively and efficiently in wartime.

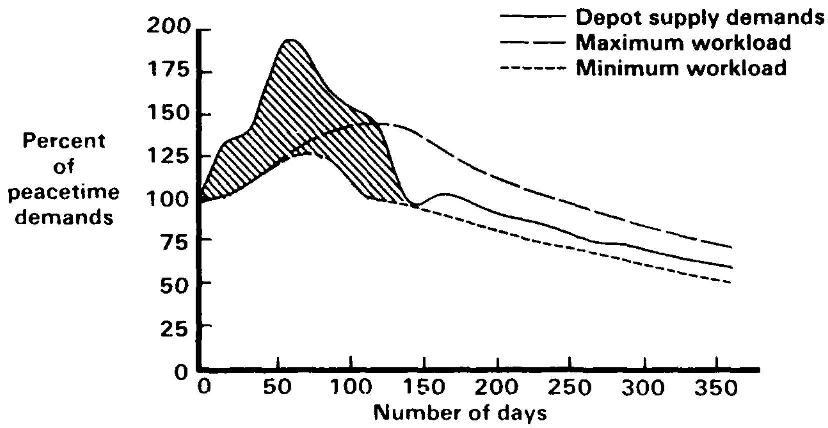

Fig. 6 -- Expected daily depot demands when pipeline times are exponential (12-month scenario)

The shaded area in Fig. 6 between the demands on depot supply curve and the minimum workload curve represents demands on depot supply that cannot be satisfied from depot repair; hence, stock must be bought to fill these demands. Note, however, that the stock buy for the exponential pipeline case is somewhat less than that required for the fixed pipeline case where the minimum workload barely rises above peacetime levels. Because we believe that these pipeline times--exponential with a fixed delay--are more representative of the real world, we used them to perform the remainder of our sensitivity analyses.

DEPOT WORKLOAD: 24-MONTH SCENARIO

Figure 7 reflects the first 12 months of the Baseline Study's 24-month scenario. Note that all these cases rise slightly above peacetime levels but eventually fall below because of attrition and reduced flying. We found that the respective peak demands on depot supply and minimum and maximum workloads were from 10 to 35 percent less for this scenario than for the 12-month scenario. However, the demands on supply and minimum workload curves remained above peacetime levels for 85 and 70 days longer, respectively, for the 24-month scenario. In

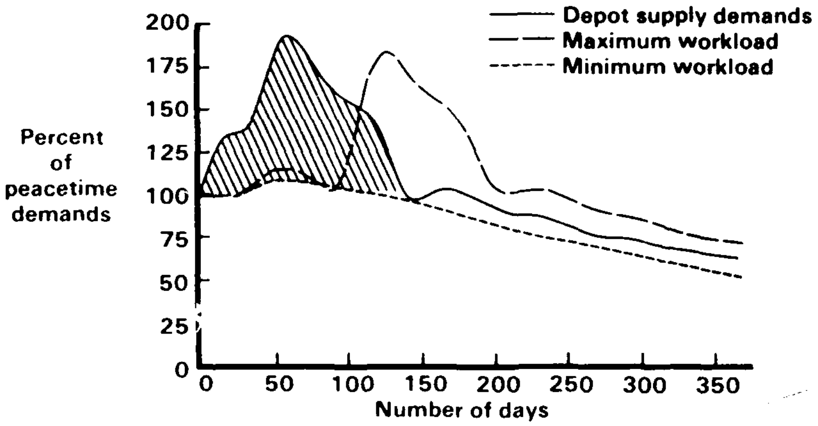

Fig. 5 -- Expected daily depot demands when pipeline times are fixed (12-month scenario)

DAILY DEPOT WORKLOAD: EXPONENTIAL PIPELINE TIMES

Although we felt that the assumption about fixed pipeline time was pessimistic, we also felt that using completely exponential pipeline times was overly optimistic. That is, some parts would arrive too soon. We therefore combined a fixed delay with exponential retrograde transportation, repair and OST times for the same 12-month scenario as shown in Fig. 6. Our mixed exponential and fixed pipeline times allow for some priority shipment and/or repair but there is a minimum fixed time before a component can arrive at the depot. The demands on depot supply remain the same. What changes are the maximum and minimum workloads.

Note that both the maximum and minimum workloads begin to arrive sooner and that the maximum peak demand on repair drops from 180 percent of peacetime to 145 percent, whereas the peak minimum workload rises from 110 percent of peacetime to about 130 percent. Because the peak maximum workload is less than 160 percent of the peacetime workload, the current estimate of how much the depot can increase output with current manpower suggests that current manpower may be sufficient to meet wartime demands if our base case with its underlying assumptions reflects actual wartime conditions.[1]

[1] Changes in either demand or BCM rates would influence these estimates.

capacity and continuous resupply (i.e., no interrupts in the retrograde or OST pipelines). Last, we did not add component workload from the Navy's SDLM.

WORKLOAD ESTIMATES: 12-MONTH GENERAL WAR

For our first prototype evaluation we used the Baseline Study's 12-month general war scenario with fixed (expected-value) repair and transportation times. Figure 5 shows the resultant projected expected daily depot workload as a percentage of peacetime demands. The solid curve to the left plots demands on depot supply. As flying increases it rises to about 195 percent of peacetime demands on the 60th day of the war. Then, as attrition and reduced sortie rates reduce total daily flying hours, demands on depot supply begin to fall. The broken curve immediately to the right represents the maximum workload. There is a considerable lag between the time demands are placed on depot supply and the time the parts arrive at the depot in this fixed pipeline time example. Note the small peak before the large peak and the reduced height of the large peak in the maximum workload. This is because shore stations have shorter retrograde times than the ships, and some parts arrive sooner than others. Thus, as the aircraft levels, flying hours, and BCM actions are reduced at the shore stations, components from the ships start arriving. The peak on the maximum workload curve is shifted about 65 days out in time and reduced from the 195 percent peak in demands on depot supply to 180 percent of peacetime demands. Finally, the dashed minimum workload curve is nearly flat with a peak of only 110 percent of peacetime demands. This occurs because flying has dropped off considerably by the time repaired components can be returned to local supply. The shaded area between the minimum workload curve and the depot supply demands represents the total stock needed to support this scenario if the component transportation times are fixed.

We believe this fixed pipeline case is too pessimistic. The Navy logistics system has some flexibility to expedite retrograde transportation and repair of critical parts. Thus, some parts will move through the system faster than the average and others will lag behind.

Table 1

DYNA-METRIC COMPONENT DATA ELEMENTS AND SOURCES

Data Element	Source
Demands per Aircraft Flying Hour	ASO Report MK0001 and Report 4790
BCM Fraction	ASO Report MK0001
Repair Time (days)	ASO Report MK0001
Depot Repair Time (days)	SIEG
Depot Condemnation Rate	SIEG
Unit Cost	SIEG
Quantity per Aircraft	1.0 (a)
Order and Ship and Retrograde Time (days)	CNA Study

(a) Because demands were per aircraft, not per component flying hour.

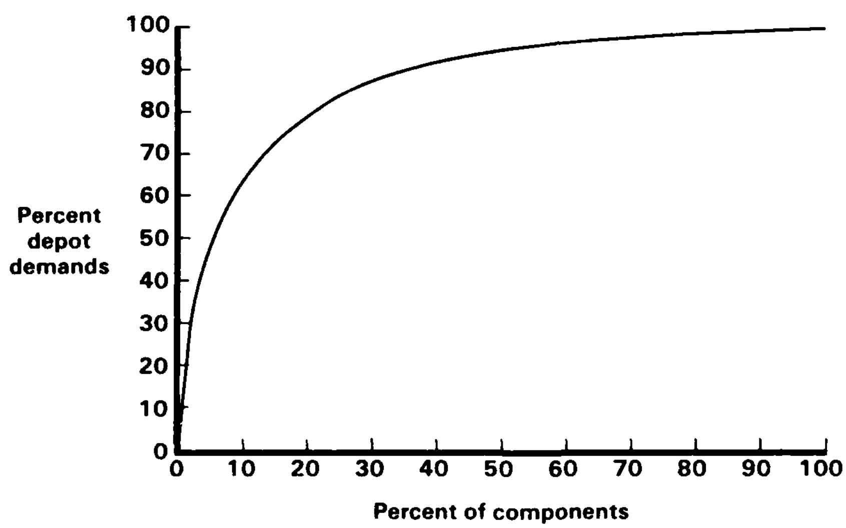

Fig. 4 -- Relationship between number of component depot demands and number of different components

the same in wartime as in peacetime. Wartime operational data could, of course, be substituted if they were available. We also assumed that component failures are generated from a simple Poisson distribution with a variance-to-mean ratio of 1.0. We further assumed ample repair

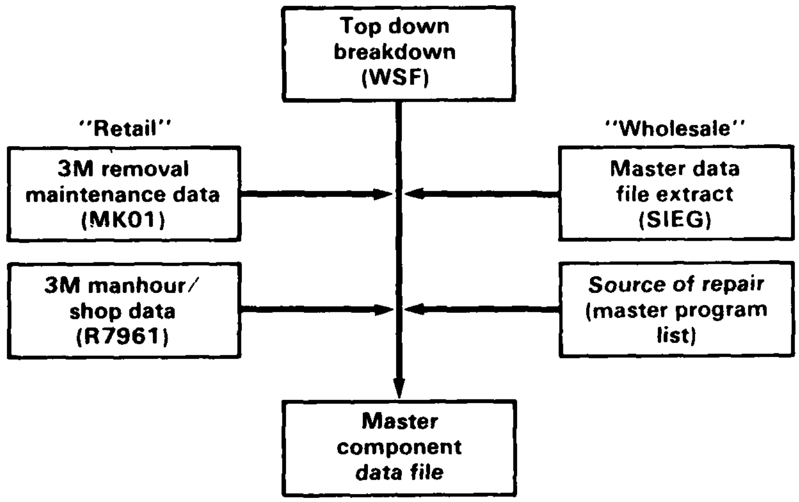

Fig. 3 -- Master component data base formulation

Two different "base case" scenarios developed for the Navy's Baseline Study were used in our analysis: a 12-month general war and a 24-month limited war. Several hypothetical sensitivity excursions from the base case scenarios were used to demonstrate the sensitivity of depot workload to retrograde and repair times and to sortie and attrition rates.

Before beginning our workload analysis we ranked our TMS component data by relative average demands at the depot. As Fig. 4 shows, we found that about 20 percent of the components represent the bulk (80 percent) of the demands at the depot. Although we chose to look at all component workloads generated by this one TMS, Fig. 4 suggests that a good proxy for workload can be found by looking at a few carefully selected items.

ASSUMPTIONS

Before discussing results it is important to review a number of key assumptions made in the analyses. The component removal and repair data were extracted from peacetime history records and may not always reflect wartime conditions. We assumed that expected removals were proportional to flying hours and that the demand rate per flying hour did not change from peacetime to wartime. Thus, the mix of component arrivals will be

III. PROTOTYPE ANALYSES USING THE WORKLOAD FORECASTING MODEL

To demonstrate the use of Dyna-METRIC for workload forecasting a prototype evaluation was conducted for one Navy TMS. This section describes the data elements used in the analysis and the results of the evaluation.

DATA BASE FORMULATION

Since the Navy does not typically keep component data by TMS, a master component data file was created to support the analyses. Data drawn from a variety of Navy sources were integrated. The ASO assisted in identifying data element sources and supplied the data to Rand. The primary sources of data for the data base were:

- ASO Weapon System File (WSF) Top Down Breakdown (TDBD);
- Family Matrix Tape (Maintenance, Manpower, and Material Data System) (3M);
- 3M Report MK0001;
- ASO Master Data File--Selective Item Extract Generation (SIEG);
- Historical Operational Data Naval Maintenance Support Office (NAMSO) Report 4790; and
- NAMSO Report 7961.

These data systems are described in the Appendix.

Figure 3 shows schematically how the master data file was created. A TDBD extract from the ASO WSF was used to identify the components installed on the specific TMS. This list of components was then used to extract retail data from the 3M data system. These data included removals, repair times, and BCM actions. Depot repair data for these components were obtained from ASO's Master Data File. Table 1 lists key component data elements needed to run Dyna-METRIC and the sources of data used for this analysis.

hour), and BCM rates, average repair times, and repair locations. And third, the model needs resource data on transportation and delay times, the number and location of aircraft, and spare components.

Model outputs related to workload estimation include both daily and cumulative number of component demands on supply, demands on depot repair (maximum workload), repair output, and minimum workload. In addition, the model computes the quantity and cost of stockage needed to fill the retrograde and depot repair pipelines.[*]

Validity

The Dyna-METRIC model has been used extensively both within Rand and by the Air Force during its more than five years of development. The underlying mathematics have been thoroughly checked by Rand and by other users. Its results have been verified by actual exercises and one version is currently being institutionalized into standard Air Force planning processes.

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[*] Depending on how it is used, the model can produce a number of other outputs including expected sorties, fully mission capable aircraft, and local stockage requirements.

repair plus shipment time before a component can be returned to local supply (Point 3 in Fig. 1). By this time, local demands for components have decreased as a result of attrition and decreased flying hours (see the left-most curve). Thus, it is necessary to repair only a fraction of the components received at the depot. The shaded area below the first curve and to the right of the third curve represents the total (cumulative) minimum workload with the dotted lines representing the daily minimum workload.

Sizing the depot to handle the maximum workload would probably be overly conservative. Alternatively, sizing it to handle only the minimum workload would provide little "insurance" against unforeseen increases in demand. This range, however, bounds the problem for a given set of assumptions. Depot surge capacity should be provided to cover demands that lie somewhere between the minimum and maximum workload curves.

The shaded area under the first curve and to the left of the third curve represents the total stock needed to support the forces until repair can take over. Note that stock needs are independent of depot capacity as long as the depot can repair the minimum workload. We will show later how the amount of this stock is affected by retrograde and repair times as well as by changes in the operational scenario.

Model Inputs and Outputs

As with any model, the quality of the workload estimates is only as good as the accuracy and thoroughness of the data inputs and the validity of the modeling assumptions. The model requires three basic types of input data.

First, the model needs scenario data concerning both the flying program and the logistics system performance. The model was designed to accept inputs by aircraft type, model, and series (TMS). However, because the Navy typically keeps these data by component, we have provided an option to specify the flying program by component.[7] Second, the model needs data on component demand rate (failures per flying

[7] The Navy's Program Data Expansion can be used to develop component flying programs for use as an input to the model.

The model relates depot workload to the operational and logistics support scenario. As mentioned above, workload is determined by a number of interdependent factors. The model combines the flying scenario with the interaction of BCM actions, asset levels and location, and location-specific retrograde and order and ship times. It produces the daily and cumulative minimum and maximum workloads for each component at specified points in the scenario.

Figure 2 illustrates how the model looks at workload and helps to clarify the definitions of minimum and maximum workload. Hypothetical wartime demands are plotted over time as a percentage of peacetime workload--the dashed straight line beneath the curves.

The left-most curve represents BCM actions or demands on the wholesale supply system from local supply (Point 1 in Fig. 1). Although these demands increase above peacetime in the hypothetical conflict, they also eventually decrease because of a decrease in the flying program and/or attrition losses. As was discussed above, these demands do not arrive at the depot until a retrograde time later. Thus, the second curve represents maximum workload or demands on repair (Point 2 in Fig. 1). As is shown by the third curve, it takes an additional

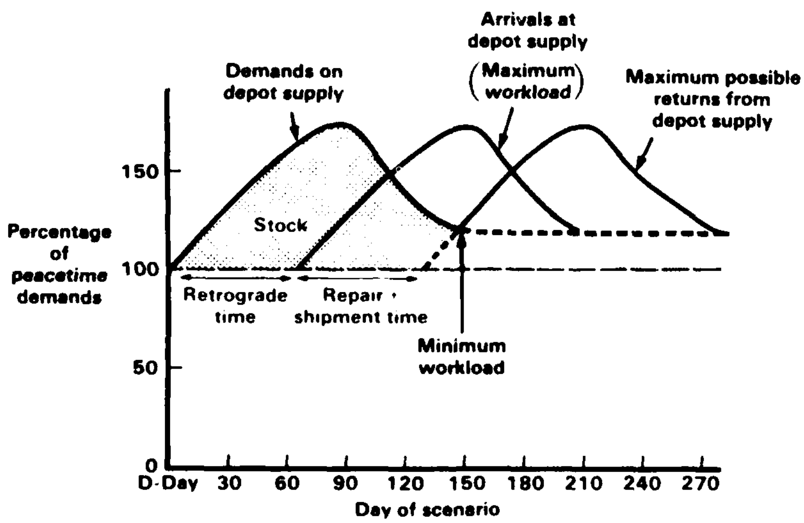

Fig. 2 -- Hypothetical wartime component depot demands and resource requirements

One of the major problems with estimating wartime workload is that the magnitude and timing of workload peaks is influenced by many interdependent factors within the logistics system. Changes in the level of flying activity over time probably have the largest effect on the workload peaks. However, the rapidity and effectiveness of the AIMD's component repairs,[3] the responsiveness of the transportation system, and the availability and positioning of spare assets also influence the volume, duration, and timing of the peak workload. Consequently any model used for workload forecasting should capture these dynamics and interdependencies. Such a model could also be used to assess component support policy options.

The Workload Forecasting Model

The capability to make component workload forecasts like those described above was incorporated into Rand's Dyna-METRIC model. The extended model, like earlier versions, is analytic, stochastic, and dynamic.

An analytic model yields a closed form solution after one run as opposed to a simulation that requires many runs (100 to 1000) to yield a statistically significant solution. Because the model is stochastic, it is typically run with a probability distribution about the expected demand rates, transportation times, repair times, etc., although it can be run with expected value transportation and repair times. The following analyses used the Poisson and exponential distributions for component failures and transportation and repair times, respectively.[4] Last, because the model is dynamic (as opposed to steady-state) and has memoryless properties,[5] it can deal with changes and/or delays in the scenario parameters.[6]

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[3] Repair times and BCM rates.

[4] The binomial and negative binomial distributions can be substituted for the Poisson by changing the variance-to-mean ratio of component demand rates from 1.0 to a number less than or greater than one, respectively.

[5] The underlying mathematics only requires knowledge of pipeline status from the end of the previous period to calculate pipeline values for the current period.

[6] See Refs. 3-5 for a detailed description of Dyna-METRIC's underlying mathematics, and Ref. 6 for the model's motivation, capabilities, and uses.

After a part has arrived at the depot it may take as long as five months to repair. Once repaired, CNA estimated that it takes an average of 15 to 40 days to deliver a part to the shore stations or carriers (Point 3 in Fig. 1) from the depot (i.e., the order and ship time (OST) is 15 to 40 days). Thus it takes an average of three and a half to eight months before depot repair can directly support the aircraft on the carrier. As will be illustrated later, by the time depot repair can play a major role in the conflict, operational needs may have changed significantly.

Because of these lags in the depot repair system, an inventory of spare stock is needed both on the carrier and at the depot to fulfill demands until depot repair can begin to serve as the primary source of serviceable components. Not surprisingly, the longer the lags, the more stock is needed. Thus, required stockage levels are determined not only by failure rates and the flying program, but also by the lengths of the retrograde, repair, and order and ship times.

The time lags between component failure, induction into depot repair, depot repair, and return to local supply can be used to define two distinct workloads, minimum and maximum. The maximum workload assumes that all components received at the depot are inducted at the time of receipt and repaired, whereas the minimum workload assumes that only those components that can be used to support the projected flying program a lead time away are inducted and repaired. Where the lead time used to compute the minimum workload is the sum of the depot repair time plus the OST. These concepts will be illustrated graphically later in this section.

WARTIME DEPOT WORKLOAD ESTIMATION

As was noted in Sec. I, forecasts of wartime depot workloads are needed to address a number of interrelated problems. For example, selecting a component's source of repair requires an estimate of the number of components expected. Because the same facility is frequently used to repair a range of components, selecting the mix of in-house (organic) and contractor repair requires knowledge of both the level and mix of expected workload. Wartime workload estimates are also needed to size organic capacity and to support any depot modernization efforts.

Figure 1 also depicts the Navy's three different types of repair and supply facilities, afloat, ashore, and at depots in the Continental United States (CONUS). Repair facilities both afloat and ashore include flight line and intermediate level (Aviation Intermediate Maintenance Departments--AIMDs) maintenance, whereas depot-level maintenance is performed at either a contractor's facilities or a Naval Air Rework Facility (NARF) in the CONUS.

As aircraft fly they experience component failures. These failures tend to increase or decrease with the flying activity (i.e., flying hours, sorties, or landings). Thus as the flying changes, so does the number of failures experienced. When a component fails it is sent to the AIMD for repair and a replacement is obtained from local (on-board or NAS) supply, if available. If a replacement is not available the aircraft may be grounded or rendered incapable of executing some of its missions. Meanwhile, the failed part is either repaired at the local AIMD and returned to local supply or it is Beyond the Capability of Maintenance (BCM) and enters a long retrograde pipeline to the depot as shown in Fig. 1. When the part is sent to the depot a demand is placed on depot (wholesale) supply (Point 1 in Fig. 1).[1]

A Center for Naval Analysis (CNA) study (Ref. 2) estimated that it takes an average of from 40 to 90 days for a failed component to arrive at a depot (i.e., from when a demand is made on depot supply until the demand or depot repair occurs). The depot cannot repair a part until it physically arrives at the depot facilities (Point 2 in Fig. 1).[2] Thus, each component experiences a time lag that is equal to the retrograde time before it can enter depot repair. As we will show later, this lag is very important in determining not only the timing but also the magnitude of depot workload.

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[1] There are some deviations to this general description of system operation. For example, some parts that fail aboard carriers may be sent at Type Commander (TYCOM) discretion to a shore AIMD because of deficiencies in on-board repair. However, this is seldom done and the data on such repairs are not available in standard data systems. In addition, some demands may be placed on an intermediate level of inventory such as that maintained at Subic Bay.

[2] Peacetime backlogs of unserviceable items that are "excess" to peacetime requirements may be inducted in the early stages of conflict.

II. DEPOT WORKLOAD FORECASTING

This section briefly describes some of the complexities and interdependencies of the Navy's logistics system and discusses the impact they have, in addition to scenario dynamics, on depot workload forecasts. The workload forecasting model and its treatment of these complex interdependencies is also described.

NAVY'S LOGISTICS SYSTEM

The primary mission of the logistics support system is to support flight operations wherever they may occur during both peace and war. Figure 1 is a schematic representation of the Navy's aviation logistics support system.

As is indicated by Fig. 1, the Navy operates aircraft both afloat and ashore. During peacetime about half of the flying is concentrated ashore at the Naval Air Stations (NASs). During wartime total flying increases substantially and the flying emphasis shifts to the Navy's deployed aircraft carriers (CVs) from which combat missions are flown.

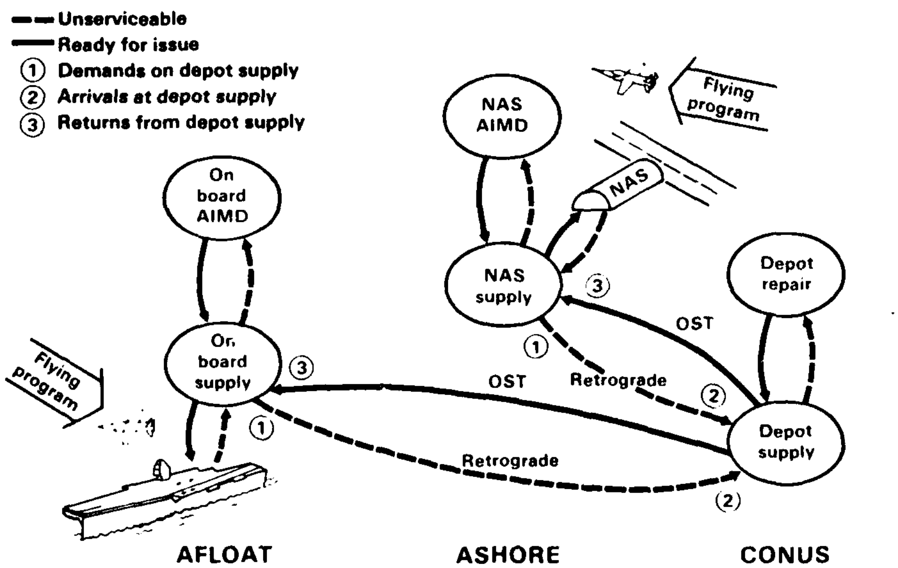

Fig. 1 -- Navy spares support system

WARTIME LOGISTICS REQUIREMENTS COMPUTATIONS

Rand has been involved in wartime capability assessment and component workload estimation studies since the late 1970s.[4] The studies resulted in the development of models of the component support system. Rand was involved in the early formulations of the Baseline Study and recognized the potential for Rand's models to satisfy the Navy's need for depot-level component workload forecasting. Consequently Rand was asked to further investigate uses of the models in the Navy and to conduct a prototype evaluation of a depot workload forecasting model.

This Note documents the results of the prototype analysis. Its objective was to demonstrate an improved methodology for projecting wartime depot component workloads and to transfer the model used to the Navy. The analyses were designed to:

- consider explicitly the interactions of the depot system with other elements of the logistics system, the demand for system stock, and the dynamic nature of the wartime workload;
- generate projected depot component repair requirements and wholesale supply requirements for a variety of wartime scenarios;
- demonstrate the impact of alternative operational and logistics support assumptions on these requirements.

OUTLINE

Section II provides a brief overview of the Navy's logistics system and Rand's workload forecasting model. Section III follows with a description of the results of a prototype evaluation conducted to demonstrate the model's capabilities. A variety of sensitivity analyses performed as part of the prototype evaluation demonstrate both the importance of recognizing the effects of system interdependencies on workload forecasts and the potential benefits of improving system responsiveness. The findings are summarized and suggestions for future Navy uses of the model are made in Sec. IV.

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[4] One prominent study was the Carrier Based Air Logistics study, which dealt with wartime logistics policies for Navy aircraft [Ref. 1].

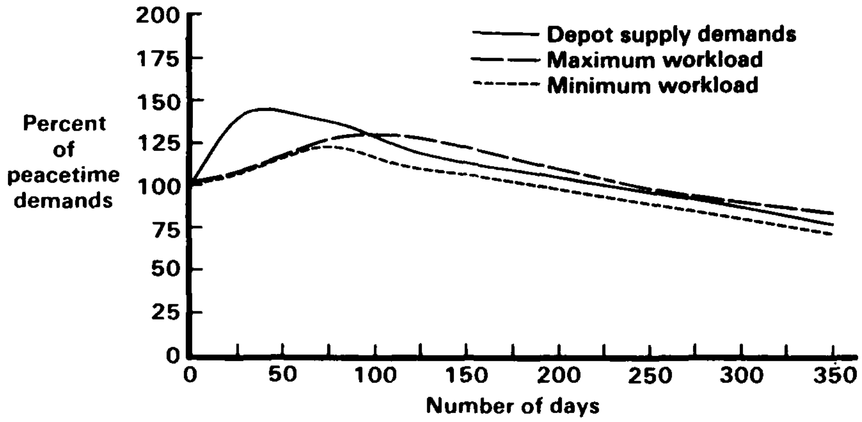

Fig. 7 -- Expected daily depot demand when pipeline times are exponential (24-month scenario)

the next 12 months of the 24-month scenario (not shown in Fig. 7 to keep the scale consistent), the curves drop another 15 to 25 percent below peacetime demands. We concluded that the 12-month scenario is more stressful for the depot system, and the remainder of this Note will deal only with the 12-month scenario.

SENSITIVITY ANALYSES: 12-MONTH GENERAL WAR SCENARIO

What happens to demands on depot supply and the maximum and minimum workloads at the depot when the retrograde time, repair time, sortie rates, attrition rates, and BCM rates are changed from those planned? The following analyses illustrate how depot workload changes with hypothetical operational or support scenario changes. For each change noted, all other factors are as in the base case (shown in Fig. 6). To show the differences in demands on depot supply and the maximum and minimum workloads, the sets of curves plotted together are different from those in Figs. 2, 5, and 6.

Retrograde Time

Figure 8 illustrates the effects on maximum workload when retrograde time is halved. Not surprisingly the peak of the maximum workload increases from 145 percent to about 160 percent of peacetime workload and shifts to the left. Of more interest is what halving the retrograde time does to the minimum workload. Figure 9 shows that when the retrograde time is halved the peak minimum workoad increases from 130 percent of peacetime workload to 145 percent.

Repair Time

When the depot repair time is also halved the peak minimum workload increases still further to 150 percent of peacetime workload. Halving both the retrograde and repair times illustrates and quantifies, with the increase in minimum workload, the larger role the depot can play during wartime when it is more closely coupled to the operational forces.

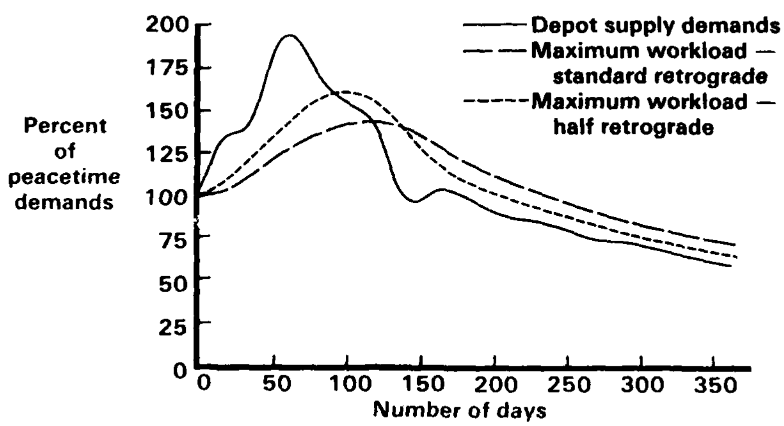

Fig. 8 -- Sensitivity of expected maximum daily depot demands when pipeline times are exponential (12-month scenario)

Recall that the shaded area between the demands on depot supply curve and the minimum workload curve represents the stock needed to cover demands that depot repair cannot fulfill. Figure 9 shows that when the retrograde and repair times are shortened, less stock and more repair are needed. Thus depot repair, an inherently more flexible resource than stock,[2] can be substituted for stock. The implication of our sensitivity analyses is that improving transportation system performance:

- reduces the need for stock;
- facilitates improved use of existing depot resources;
- permits substitution of a more flexible resource (repair) for a less flexible resource (stock); and
- leads the way to improving fleet effectiveness.

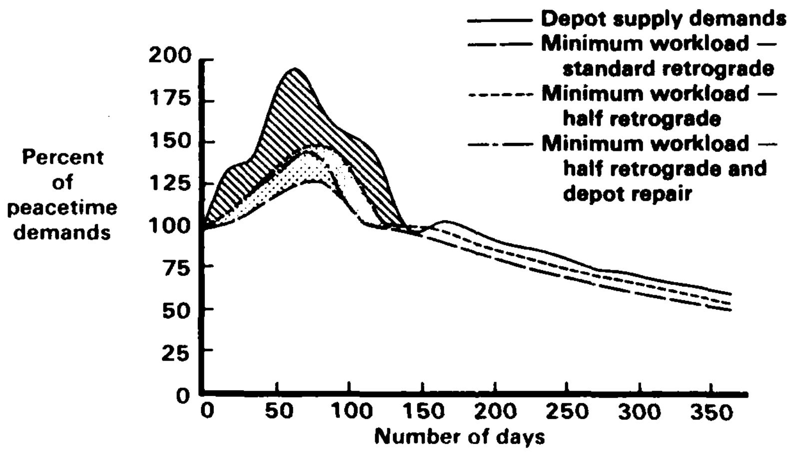

Fig. 9 -- Sensitivity of expected minimum daily depot demands when pipeline times are exponential (12-month scenario)

[2] Depot repair facilities typically repair a broad scope of components with common equipment and manpower. If demands for one particular component increase substantially above others, limited repair capacity can be focused on the problem item. Thus, priority repair can smooth the variance in component workload.

As the depot becomes more closely connected to the forces, the additional benefits of priority repair emerge. That is, instead of repairing parts first-come first-served, the depot can repair first those parts that will make the next aircraft fully mission capable. In addition, improving transportation system performance can enhance the value of a responsive depot repair system. Of course, these changes cannot occur without some additional costs. However, the primary costs may be those for establishing a responsive management system rather than purchasing of additional transportation resources.

Sortie and Attrition Rates

Figure 10 depicts what happens to demands on depot supply when the actual wartime increase in sortie rates and/or attrition rates is half of what was expected. Not surprisingly, when the increase in the sortie rate is halved, peak demands on depot supply drop dramatically--from 195 percent to about 145 percent of peacetime demands. When the attrition rate is also halved, the peak increases about 5 percent, and it flattens substantially. *Again, the more important question is what happens to* the minimum workload.

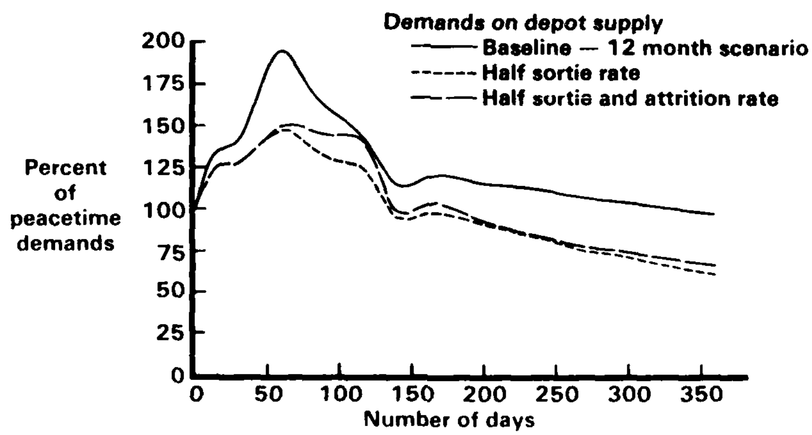

Fig. 10 -- Sensitivity of expected daily demands on depot supply to operational changes

The effect of operational changes in the scenario on minimum daily workload is illustrated in Fig. 11. The results are similar to those for the demands on depot supply; that is, when the increase in the sortie rate is halved the minimum workload decreases from about 130 percent to 110 percent of peacetime. In addition, the minimum workload rises about 5 percent when the attrition rate is halved.

The primary difference between this result and that shown earlier is the stabilization of the minimum workload, which suggests that the minimum workload estimate is fairly robust under certain circumstances.

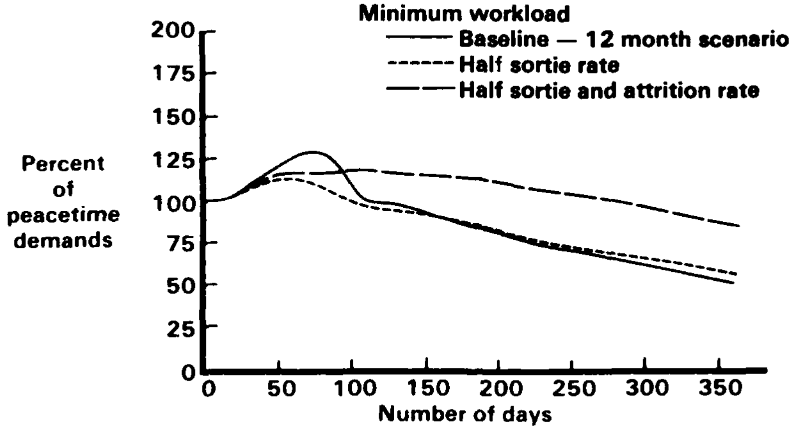

Fig. 11 -- Sensitivity of expected minimum daily workload to operational changes

BCM Rates

The percentages of components sent to the depot (BCM rates) also strongly affect depot demands. As Fig. 12 shows, when the BCM rates are increased by half (high BCM) of the difference between 1.0 and the rate (e.g., BCM = (BCM + 1)/2), demands on depot supply increase substantially to a peak of 270 percent of peacetime. And, when BCM rates are halved (low BCM) except for those that are 1.0, peak demands on depot supply fall to 115 percent of peacetime. Changes in the BCM rates similarly affect the minimum workload as Fig. 13 shows.

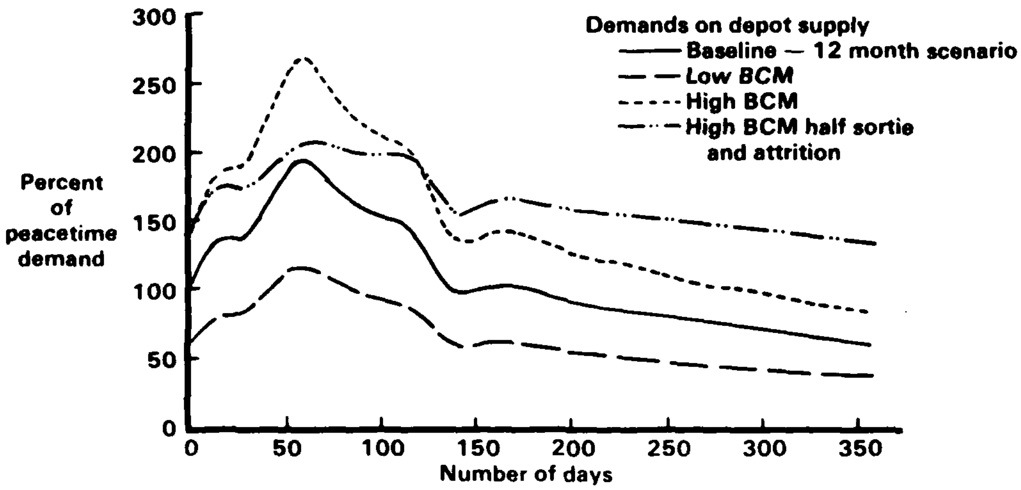

Fig. 12 -- Sensitivity of expected daily demands on depot supply to BCM rates

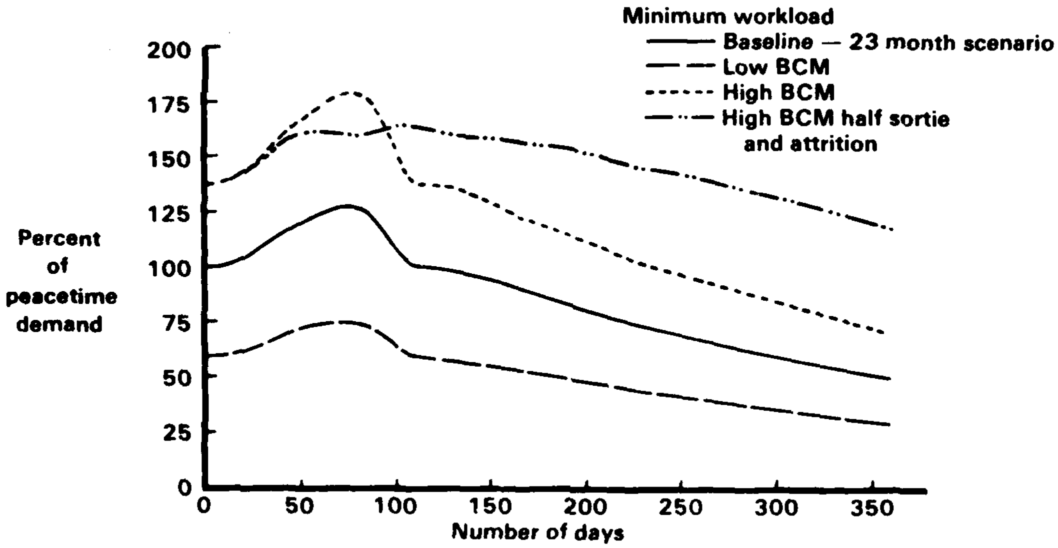

Fig. 13 -- Sensitivity of expected minimum workload (12-month scenario)

SUMMARY

Although the above analysis was done for a single TMS it is representative of what can be done with the Dyna-METRIC model. The Navy would have to expand the analysis to all components on all TMSs to get total depot workload. If manhours are required, a simple postprocessing of the results can generate total manhours as well, provided the data linking number of components to depot manhours are provided.

IV. CONCLUSIONS

The foregoing discussion has described an improved methodology--the Dyna-METRIC model modified--for projecting wartime depot component workloads, and has demonstrated that it can be used to address a broad range of relevant issues. In addition, the demonstration illustrates some of the many analyses available to assess the effects of various logistics systems elements on depot workload and supply requirements.

The depot component workload forecasting model can be used to project wartime workloads. Of course, the quality of the results depends upon both the availability and the accuracy of the data and the ability to predict ("know") what the future holds. The model has been structured to accept standard Navy data and is now available for Navy use.

The demonstration illustrates the potential benefits or payoffs of improving logistics system performance. It also shows that the model provides a capability to address a wide range of logistics issues.

This work suggests that additional Navy analysis could identify a variety of potential tradeoffs within the operational and support scenarios, and that these tradeoffs can be evaluated in terms of both fleet operational performance and cost. Although the topic was not specifically analyzed, this study suggests that improved component management systems that shorten the repair and transportation pipelines would enhance the ability of the Navy's depots to support the operational forces in wartime.

APPENDIX

PRIMARY DATA SOURCES

To develop the prototype data base it was necessary to integrate data drawn from a variety of Navy sources. With the assistance of ASO, sources of the data elements were identified and the data were obtained.

The primary sources of data used to create the data base were:

- ASO Top Down Breakdown (TDBD), August 1983;
- Family Matrix Tape, September 1983;
- 3M Report MK0001, October 1982 - September 1983;
- Master Data File--Selective Item Extract Generator (SIEG), September 1983;
- Historical Operational Data NAMSO Report 4790, August 1983;
- NAMSO Report 7961, September 1983;
- CNA Report (Ref. 2), February 1981.

PROTOTYPE DATA BASE

One TMS was used for the prototype analysis, and a list of National Stock Numbers (NSN) was obtained from a TDBD extract from ASO's WSF. A list of unique components was complied and used to extract the necessary data elements from the other sources as shown in Table A.1.

Data elements from each source were updated to head of family using the Family Matrix tape. Data were then accumulated across family members to assure that data elements (demand rate, BCM rates, etc.) were complete. The contents of the complete master component file are shown in Table A.2.

Most of the data elements contained in the file were not used for the work described in this Note. However, they were included because additional data elements were needed to support four interrelated studies that were conducted concurrently for the Navy.

The Navy also conducts internal studies that require data from the same sources used in this work. Data integration is an expensive and time-consuming task. Since the data processing necessary to integrate data from a variety of sources has already been done, this file can be used to support the Navy's own logistics policy studies.

Table A.1

DATA SOURCES

Elements	TDBD (a)	Family Matrix Tape(a)	MK0001 (b)	SIEG (a)	NAMSO Report 4790(b)	NAMSO Report 7961(b)
National Stock Number	X					
Family Group Code		X				
Cognizance Symbol (COG)				X		
NIIN Nomenclature				X		X
SM&R Code						X
Price				X		
Work Center Code						X
Total Removals			X			
Percent I-Level Repair			X			
Average Turnaround Time (TAT)			X			
Average in Process Days			X			
Average Awaiting Parts Days			X			
Average Scheduling Days			X			
Average Repair Days			X			
Percent BCM			X			
Percent BCM (Condemn)			X			
Removals per Flying Hour			(c)		(c)	
Average Depot Repair Time				X		
Depot Survival Rate				X		
Average Depot TAT				X		

(a) ASO data.
(b) 3M data.
(c) Computation element.

Table A.2

MASTER COMPONENT LIST FORMAT

Noun	Data Source	Used in This Study	Den	# of Char	Card Columns
NIIN	TDBD	X	D046D/ C002B	9	1-9
Family Group Code	SIEG	X	C001A	4	10-13
Cognizance Symbol (COG)	SIEG	X	C003	2	14-15
Material Control Code (MCC)	SIEG		C003A	1	16
Unit of Issue	SIEG		C005	2	17-18
Newly Provisioned Item Ind	SIEG		B067A	1	19
Item Demand Ind	SIEG		B067B	1	20
Itm High $ Dmd/Repl Price Ind	SIEG		B067C,D	1	21
Rep Itm/RC Itm/Nvy Rep Ind	SIEG		B067F,G,H	2	22-23
Pgm Rel for Fut/Cur Dmd Ind	SIEG		B067E,J	1	24
Shelf Life Indicator	SIEG		C028	1	25
SMIC	SIEG		C003B	2	26-27
Avg Item Essentially	SIEG		C008C (3D)	3	28-30
Prod Lead Time, Avg	SIEG		B010 (1D)	3	31-33
Federal Supply Classification	SIEG		C042	4	34-37
Source Code	SIEG		D012	2	38-39
Replacement Price	SIEG	X	B055 (2D)	8	40-47
Mfg's Set-Up Cost	SIEG		B058	8	48-55
Expected Units per Requirement	SIEG		B073	8	56-63
Procurement Lead Time Forecast(Qtrs)	SIEG		B011A (2D)	8	64-71
Current Maint Dmd Obs	SIEG		A005	8	72-79
Current Overhaul Dmd Obs	SIEG		A005A	8	80-87
Sys Random Maint Dmd Avg	SIEG		B022 (8D)	16	88-103
Item Name	SIEG	X	C004	17	104-120
Item Management Segment Code	SIEG		C003W	2	121-122
Minimum Prod Quantity	SIEG		B061B	5	123-127
System Reorder Level	SIEG		B019	8	128-135
System Order Quantity	SIEG		B021	8	136-143
Other Acq War Reserve Reqmt	SIEG		B028A	8	144-151
Approved Force Reten Increm	SIEG		B028B	8	152-159
Acq War Reserve Protctble Rqmt	SIEG		B028C	8	160-167
Sys Reorder Level Low Limit Qty	SIEG		B020	8	168-175
Total PWRMR (Purpose Code = 'A')	SIEG		A015A	8	176-183
Total PWRS (Purpose Code = 'A')	SIEG		A015C	8	184-191
System Demand During Lead Time	SIEG		B023C (8D)	16	192-207
System Demand End of Lead Time	SIEG		B023D (8D)	16	208-223
Procurement Problem Variance	SIEG		B019A (8D)	16	224-239

KEY: COMP = Computed.
MK1 = 3M Report MK0001.
( ) = No. of decimal places.

Table A.2

(CONTINUED)

Noun	Data Source	Used in This Study	Den	# of Char	Card Columns
Wearout Rate	SIEG		F007 (2D)	3	240-242
Navy Rpr In-Process Time Ave (Qtrs)	SIEG	X	B012C (2D)	3	243-245
Commercial Repair Tat (Qtrs)	SIEG		B012 (2D)	3	246-248
Repair Survival Rate	SIEG	X	F009 (2D)	3	249-251
Repair Problem Avg Tat (Qtrs)	SIEG	X	B012E (2D)	4	252-255
Average Proc Problem Tat (Qtrs)	SIEG		B012F (2D)	4	256-259
Repairable Ident Code	SIEG		D008	10	260-269
Repair Net Price	SIEG		B059 (2D)	8	270-277
System Repair Level	SIEG		B019B	8	278-285
System Repair Quantity	SIEG		B021A	8	286-293
Sys RFI Regeneration During LT	SIEG		B023E (1D)	8	294-301
Sys RFI Regeneration End of LT	SIEG		B023F (1D)	8	302-309
Sys RFI Regeneration During Tat	SIEG		B023G (1D)	8	310-317
Item Repair Cost	SIEG		B055A (2D)	8	318-325
Repair Set-Up Cost	SIEG		B058A	8	326-333
Depot Completion NIIN Current	SIEG		F020	5	334-338
Depot Survey NIIN Current	SIEG		F095	5	339-343
Below Level Surveys Current	SIEG		F022	5	344-348
Cum Qty RPRD Navy Rpt Acty	SIEG		B012H	8	349-356
Cum Qty RPRD Navy Nonrpt/Comm Rep Facs	SIEG		B012L	8	357-364
Work Center	R7961	X	WC	3	365-367
ATC A: Items	R7961		A_N	5	368-372
ATC A: ML2 Hrs	R7961		A_HR (1D)	8	373-380
ATC A: Days TAT	R7961		A_TAT	7	381-387
ATC B/C/K/Z: Items	R7961		B_N	5	388-392
ATC B/C/K/Z: AWP Items	R7961		B_AWPN	5	393-397
ATC B/C/K/Z: ML2 Hrs	R7961		B_HR (1D)	8	398-405
ATC B/C/K/Z: ML2 EMT	R7961		B_EMT (1D)	7	406-412
ATC B/C/K/Z: DAYS TAT	R7961		B_TAT	7	413-419
ATC B/C/K/Z: DAYS AWP	R7961		B_AWP	7	420-426
Work Unit Code	R7961		WUC	5	427-431
SMR Code	R7961	X	SMR	6	432-437
Noun from R7961	R7961		NOMEN 1	4	438-451
WRA Flag	COMP		WRA	1	452
Obsolescence Rate	SIEG		B057 (2D)	3	453-455
Repairable Star	MK1			1	455
Total Removals Ashore	MK1			6	457-462
Total Removals Afloat	MK1			6	463-468
Total Removals Worldwide(WW)	MK1	X		6	469-474

KEY: COMP = Computed.
MK1 = 3M Report MK0001.
( ) = No. of decimal places.

Table A.2

(CONTINUED)

Noun	Data Source	Used in This Study	Den	# of Char	Card Columns
PCT I-Level Repair - Ashore	MK1		(2D)	5	475-479
PCT I-Level Repair - Afloat	MK1		(2D)	5	480-484
PCT I-Level Repair - WW	MK1	X	(2D)	5	485-489
Average Turn Around Time - Ashore	MK1		(2D)	5	490-494
Average Turn Around Time - Afloat	MK1		(2D)	5	495-499
Average Turn Around Time - WW	MK1	X	(2D)	5	500-504
Average in Process Days - Ashore	MK1		(2D)	5	505-509
Average in Process Days - Afloat	MK1		(2D)	5	510-514
Average in Process Days - WW	MK1	X	(2D)	5	515-519
Average Awaiting Parts Days - Ashore	MK1		(2D)	5	520-524
Average Awaiting Parts Days - Afloat	MK1		(2D)	5	525-529
Average Awaiting Parts Days - WW	MK1	X	(2D)	5	530-534
Average Scheduling Days - Ashore	MK1		(2D)	5	535-539
Average Scheduling Days - Afloat	MK1		(2D)	5	540-544
Average Scheduling Says - WW	MK1	X	(2D)	5	545-549
Average Repair Days - Ashore	MK1		(2D)	5	550-554
Average Repair Days - Afloat	MK1		(2D)	5	555-559
Average Repair Days - WW	MK1	X	(2D)	5	560-564
PCT BCM (ATC 1 Thru 9) - Ashore	MK1		(2D)	5	565-569
PCT BCM (ATC 1 Thru 9) - Afloat	MK1		(2D)	5	570-574
PCT BCM (ATC 1 Thru 9) - WW	MK1	X	(2D)	5	575-579
PCT BCM (ATC 1) - Ashore	MK1		(2D)	5	580-584
PCT BCM (ATC 1) - Afloat	MK1		(2D)	5	585-589
PCT BCM (ATC 1) - WW	MK1		(2D)	5	590-594
PCT BCM (ATC 4) - Ashore	MK1		(2D)	5	595-599
PCT BCM (ATC 4) - Afloat	MK1		(2D)	5	600-604
PCT BCM (ATC 4) - WW	MK1		(2D)	5	605-609
PCT BCM (ATC 9) - Ashore	MK1		(2D)	5	610-614
PCT BCM (ATC 9) - Afloat	MK1		(2D)	5	615-619
PCT BCM (ATC 9) - WW	MK1	X	(2D)	5	620-624
PCT BCM (ATC A OR J) - Ashore	MK1		(2D)	5	625-629
PCT BCM (ATC A OR J) - Afloat	MK1		(2D)	5	630-634
PCT BCM (ATC A OR J) - WW	MK1		(2D)	5	635-639
Removals per Flying Hour - Ashore	COMP		(6D)	7	640-646
Removals per Flying Hour - Afloat	COMP		(6D)	7	647-653
Remorals per Flying Hour - WW	COMP	X	(6D)	7	654-660
Removals per Sortie - Ashore	COMP		(6D)	7	661-667
Removals per Sortie - Afloat	COMP		(6D)	7	668-674
Removals per Sortie - WW	COMP		(6D)	7	675-681
Quantity per Application	TDBD			3	682-684

KEY: COMP = Computed.
MK1 = 3M Report MK0001.
( ) = No. of decimal places.

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